

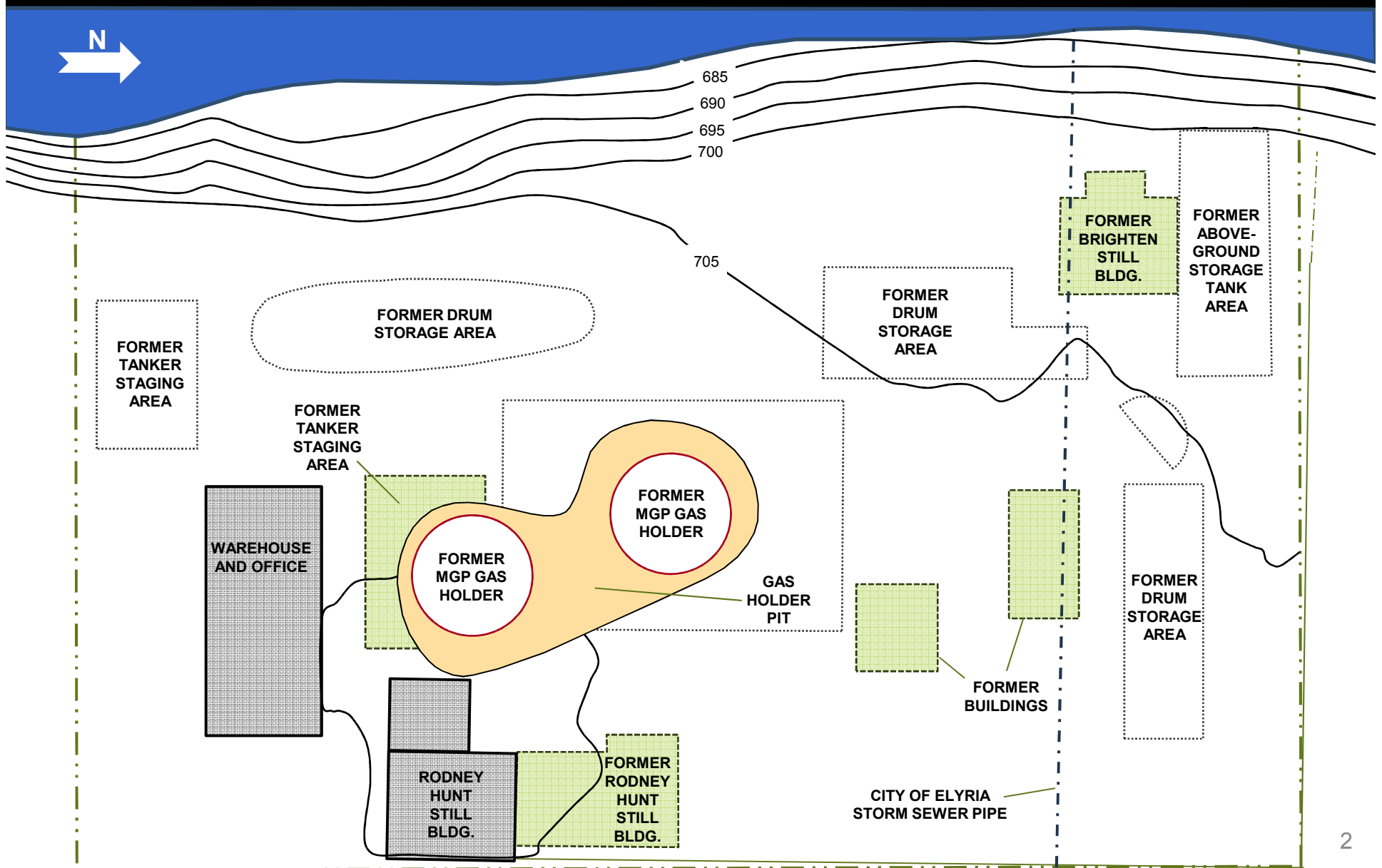
CRS Site – Elyria, Ohio

AGWS-S
Data Review

Brown AND
Caldwell



Previous and Existing Site Features



AGWS-S Scope of Work

- Temporal Water Level Data
- Seep Inspections Along East and West River banks
- River Bed Survey
- Bedrock Downhole Permeability Testing
- Surface Water Sampling
- NAPL Recovery Tests
- Bedrock Coring and Analysis of Cores
- AGWS Report
 - Revised Hydrogeologic CSM

Findings

- Findings consistent with previous understanding of hydrogeologic conceptual model.
- MGP waste/NAPL is present in the bedrock, contained in the bedrock matrix and along bedding plane fractures.
- The mobility and recoverability of the NAPL is low.
- Confirms that the site is a candidate for a Technical Impracticability Waiver.

Hydrogeologic Conceptual Site Model

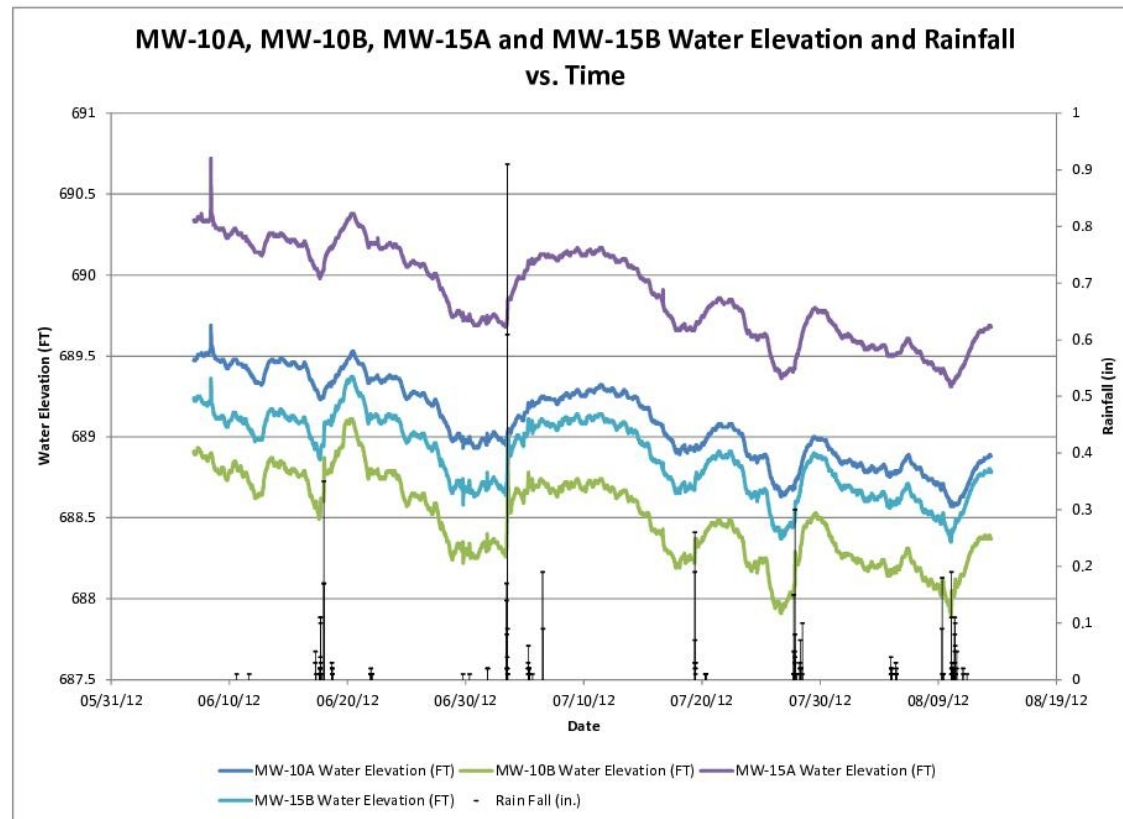
Groundwater discharging to the River is supported by five lines of evidence

1. Groundwater elevation in the bedrock is higher than the River level.
2. The seeps observed on both River banks are at similar elevations and are surface expressions of groundwater flow primarily through bedding plane fractures.
3. The River surface elevation is regulated by the downstream fixed dam and reacts consistently with site groundwater elevation in wells closest to the River.
4. The hydraulic conductivity of the bedrock indicates that there are no impediments to lateral flow to the River.
5. The response to rain events in site wells at greater distances from the river is gradual and increases the gradient to the River.

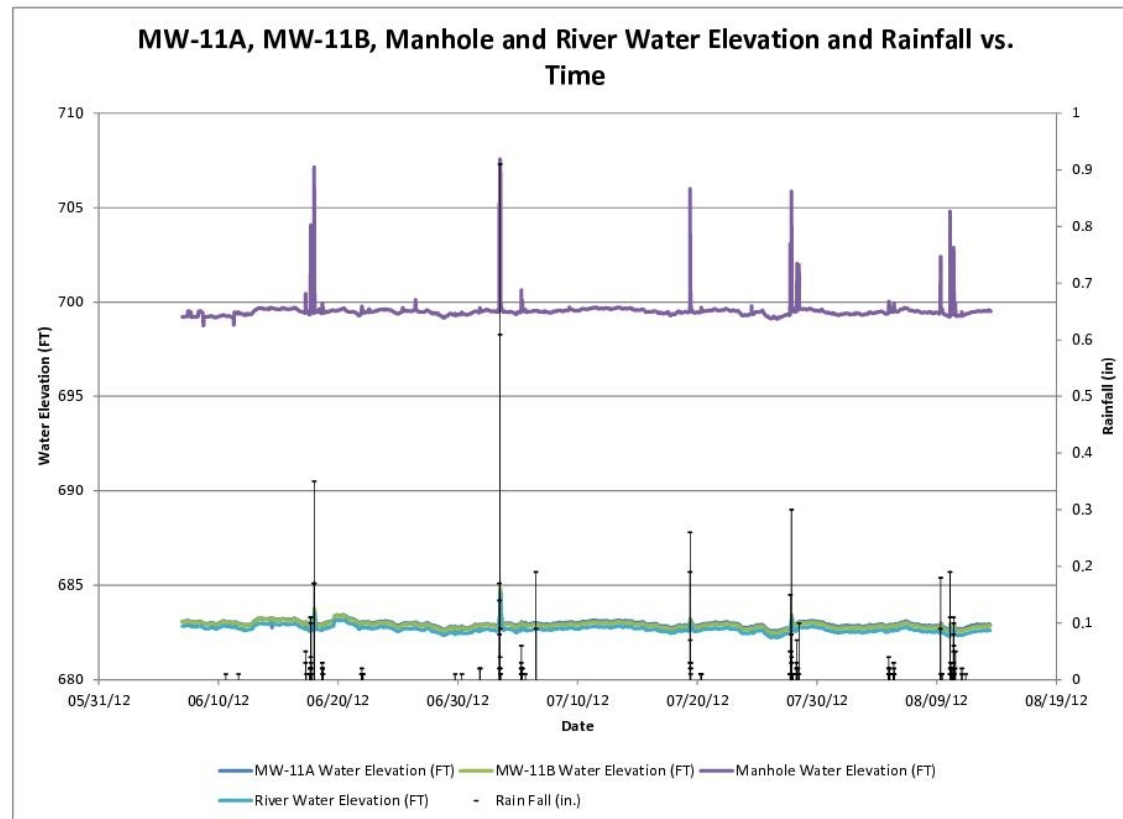
Water Level Investigation Results

- Distinct downward hydraulic gradient across most of Site from Upper to Lower Bedrock Zones to the River, decreasing toward the River.
- The MW-11 couplet and the River appear to be in direct hydraulic connection, as shown by nearly identical water elevations.
- The manhole water elevations reacted quickly and significantly (rise of about 8 feet to near top of manhole) during and immediately following the significant rain events, but then quickly subsided.
- The River elevation reacted quickly to the significant rain events and quickly rose up to 2 feet, but then in general dropped to within a couple tenths of a foot of base flow within an hour or two.
- Water levels in the wells responded more slowly and gradually to the rain events, generally taking a couple of days to reach maximum response elevation, then gradually decreasing toward static conditions.
- The River elevation appears to be regulated by the East Branch Dam/Falls, located less than ½ mile downstream from Site.
- Divided bedrock into Upper Bedrock Zone (UBZ - wells screened above 667' msl) and Lower Bedrock Zone (LBZ - wells screened below 667' msl).
- The horizontal hydraulic gradient in both the UBZ and LBZ is toward, and discharges into the River, with a deflection toward the MW-11A/B well couplet near the storm sewer outfall.

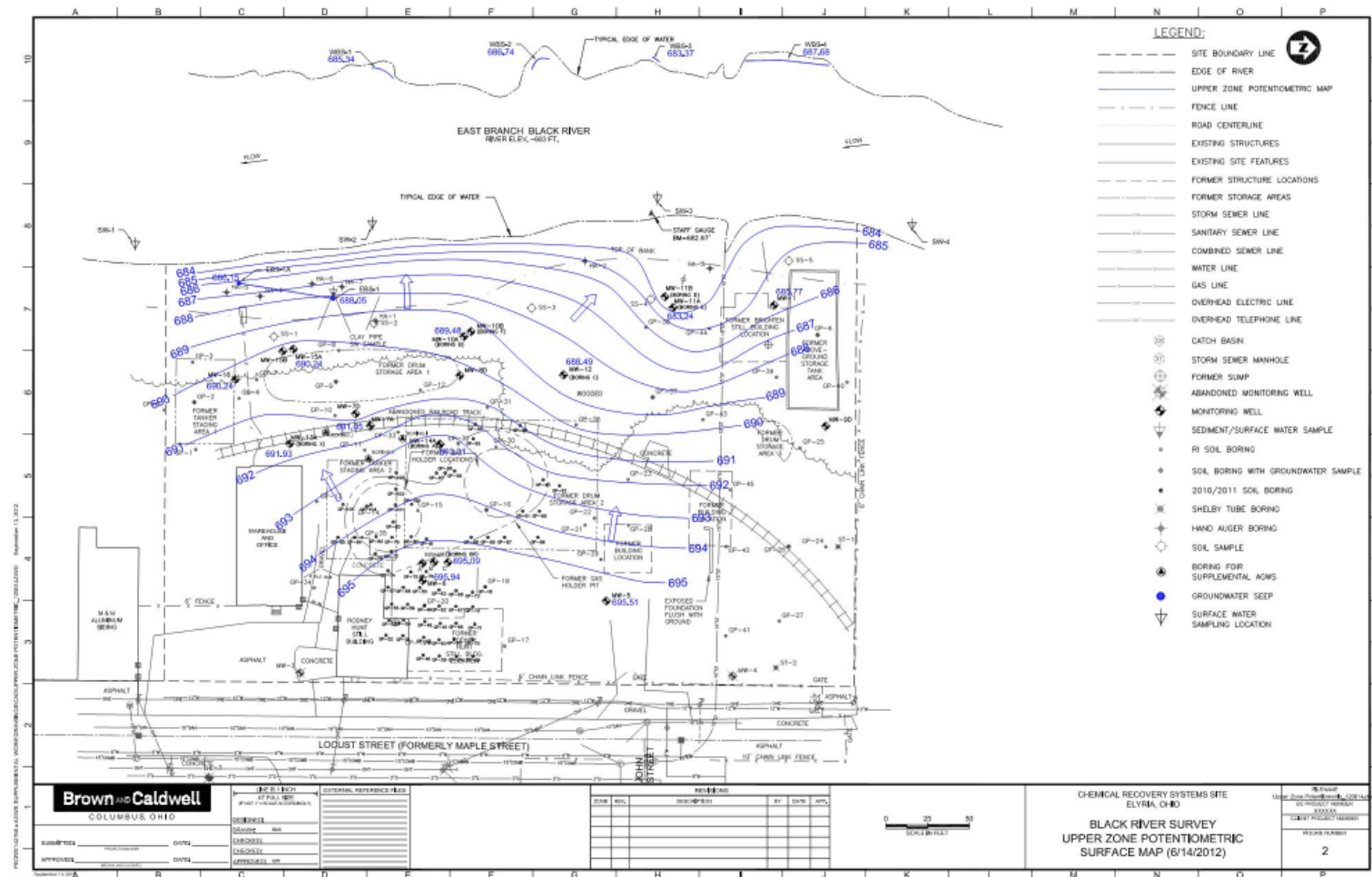
Water Level Investigation Results



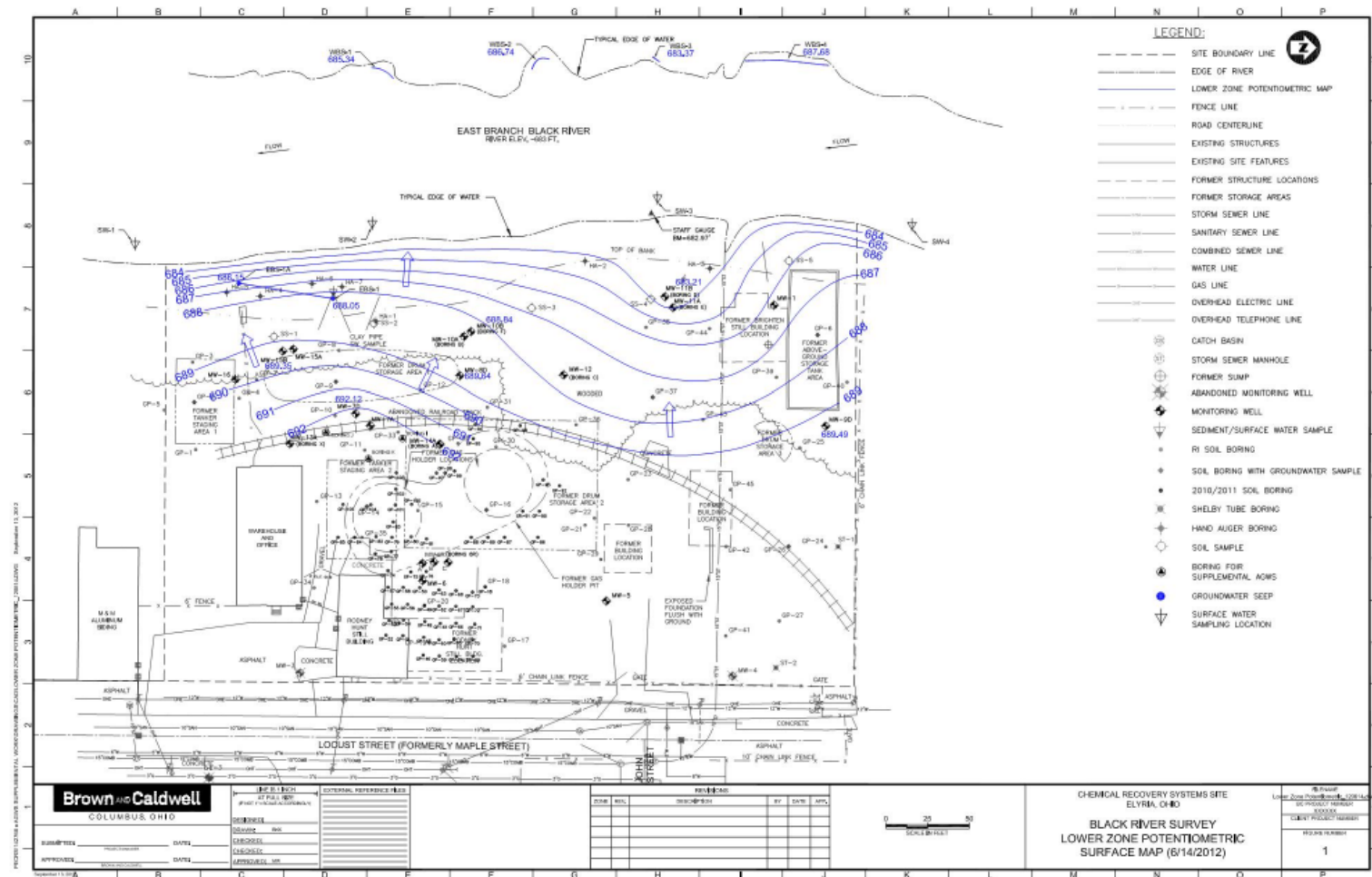
Water Level Investigation Results



Water Level Investigation Results



Water Level Investigation Results



Seep Inspection Results

Seep ID	Description	Elevation	Flow
EBS-1	East bank, bedrock bedding plane	688.05' msl	Wet; minor sheet flow
EBS-1A	East bank, drips from bedrock overhang	688.14' msl	0-0.03 LPM
WBS-1	West bank, bedrock bedding plane	685.34' msl	Wet; minor sheet flow
WBS-2	West bank, from roof of cavern	686.74' msl	Wet; minor sheet flow to a couple sporadic drips
WBS-3	West bank, bedrock bedding plane	683.37' msl	Wet; minor sheet flow
WBS-4	West bank, bedrock bedding plane (moss)	687.68' msl	0.1-0.3 LPM

- The east bank seep elevations (688' msl) and west bank seep elevations (685-687' msl) are similar, compared to the River elevation of approx. 683' msl, indicating groundwater flow from similar horizons into the River from both riverbanks.

River Bed Survey-Scope

- More than 500 survey points of river bed adjacent to Site and across full width of River.
- Surveyed top of bedrock and top of sediment.
- Surveyed River's edge.

Bedrock Packer Testing Results

- The Berea Sandstone at the Site has primary (unfractured zones) K values in the 10^{-4} to 10^{-5} cm/sec range.
- Some bedding fracture zones have K values of 10^{-3} cm/sec, or greater.
- The highest K values were observed in MW-10A and MW-15A at similar elevations, and generally consistent with the elevation of the east bank seeps.

Surface Water Sampling Results

- The only SVOC detected was the herbicide atrazine, detected in all samples at 1.1 to 2.1 ug/L (< MCL).
- No VOCs detected in furthest downstream samples (SW-1 and SW-2).
- Trace levels (< 1 ug/L and J-qualified) of chloromethane, c12DCE and 124TCB were detected in the upstream samples (SW-3 and SW-4), but below the MCLs and Region 9 PRGs (2006 RI).
- Proposed 2nd and 3rd rounds of samples not collected due to lack of sustained increase in river stage. East Fork dam, less than 0.5 mile downstream appears to regulate river stage.
- A 2nd round of surface water samples were collected from the initial SW monitoring locations on September 11, 2012, in accordance with the work plan modification approved by U.S. EPA.

NAPL Assessment

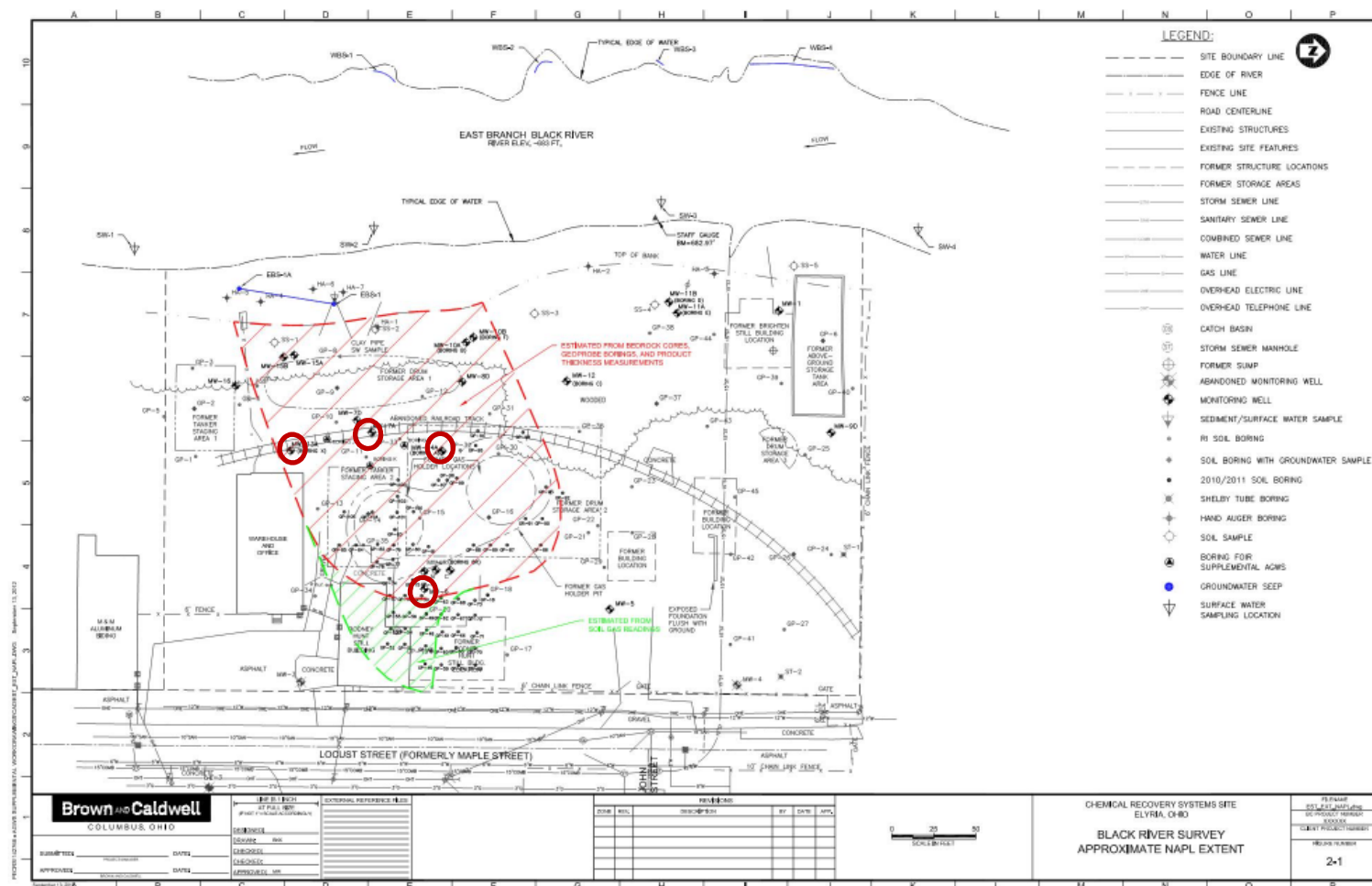
- Focus was on:
 - Further defining the lateral and vertical extent of impacts;
 - Physical and chemical properties of the NAPL; and
 - Mobility and potential recoverability of NAPL.

Methodology employed well sampling, rock coring and chemical and petro-physical testing.

NAPL Assessment

- Key findings from the assessment:
 - The NAPL CSM previously developed still holds.
 - Highest NAPL saturations in close proximity to the former operational areas (gasometers and coal tar pits).
 - Based on the age of the NAPL it would be highly weathered with moderate to high viscosities.
 - NAPL impacts will be present above, at and below the water table.
 - NAPL will exhibit limited to no mobility and recoverability.
 - Main COPC's from the MGP materials comprised of BTEX and PAHs but other COPCs from CRS operations are co-eluted within the NAPL.

NAPL Recovery Tests-Results



NAPL Recovery Test Results

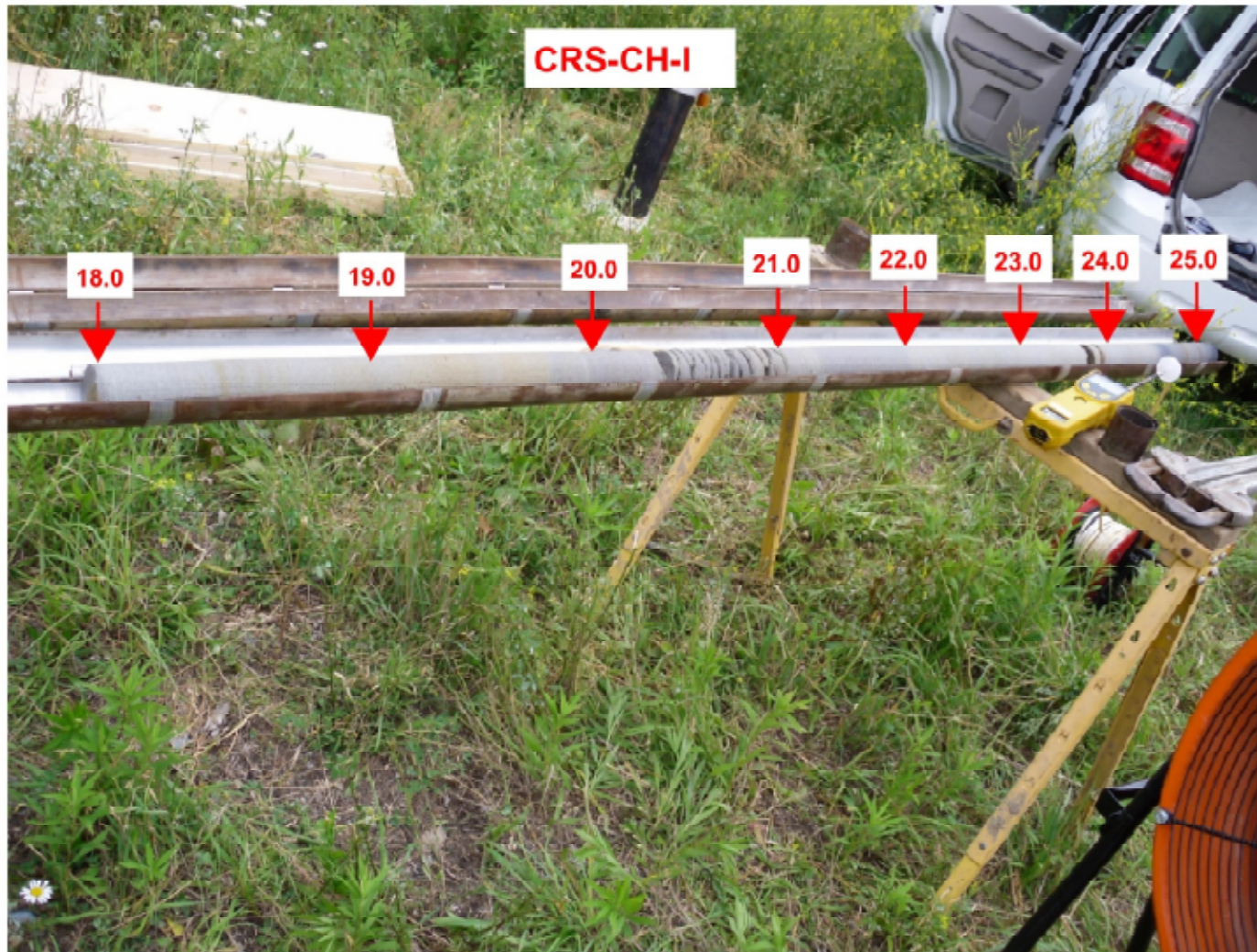
- Field data indicates LNAPL has limited mobility and recoverability.
 - No LNAPL or DNAPL observed in wells MW-6 and MW-13A (wells where NAPL historically observed).
 - Limited observations of globules of NAPL in MW-7A and MW-14A; but could not recover any during testing.
 - The absence of NAPL precluded bail down testing.

Conclusion the majority of the mass is trapped as residual NAPL within the rock matrix.

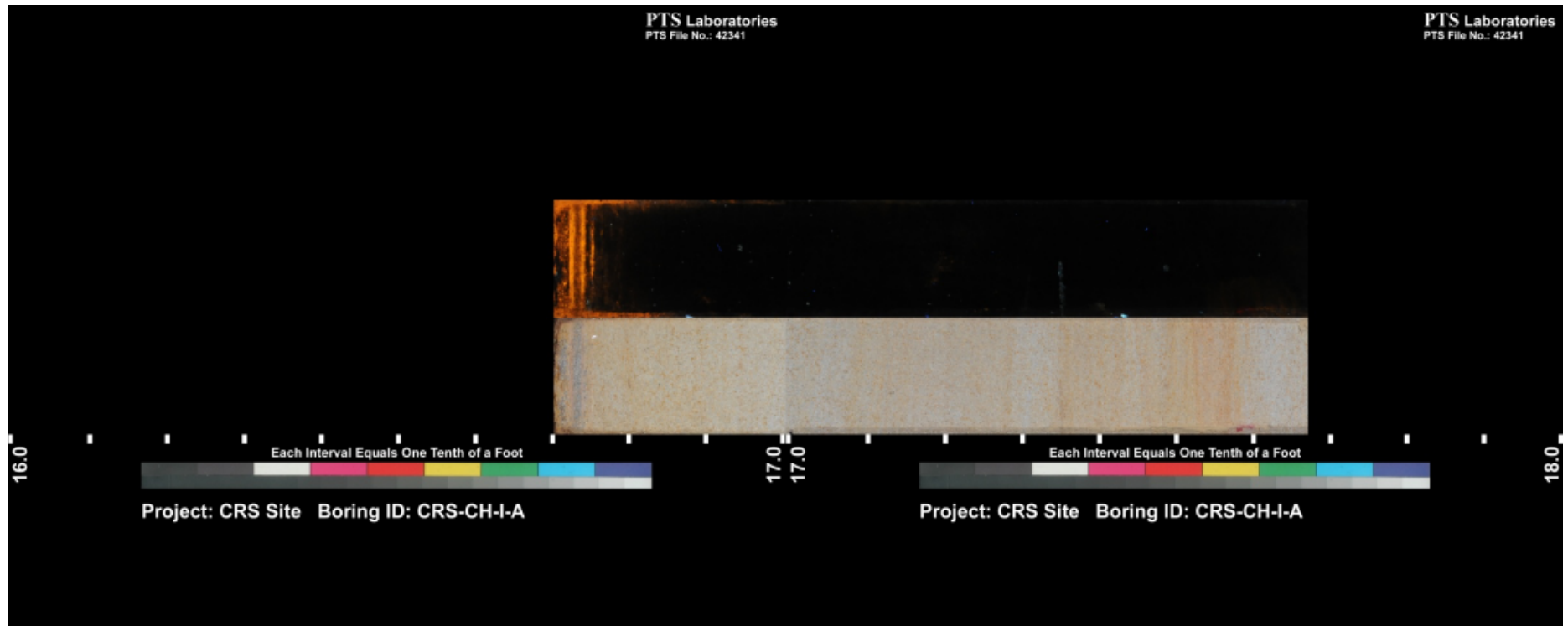
Bedrock Coring and Analysis-Scope

- Three core holes (CH-I, CH-J and CH-K) were completed to depths ranging from 25 to 30' bgs. Coring was terminated when “clean” bedrock was encountered beneath impacted zones.
- Work supplemented the previous bedrock assessments conducted in the area of NAPL impacts.
- Subsections of rock core from each core hole were submitted for chemical analysis and petrophysical testing.
 - Core photography/fluorescence, pore fluid saturation, grain size, porosity, residual saturations, and oil displacing oil imbibition tests.

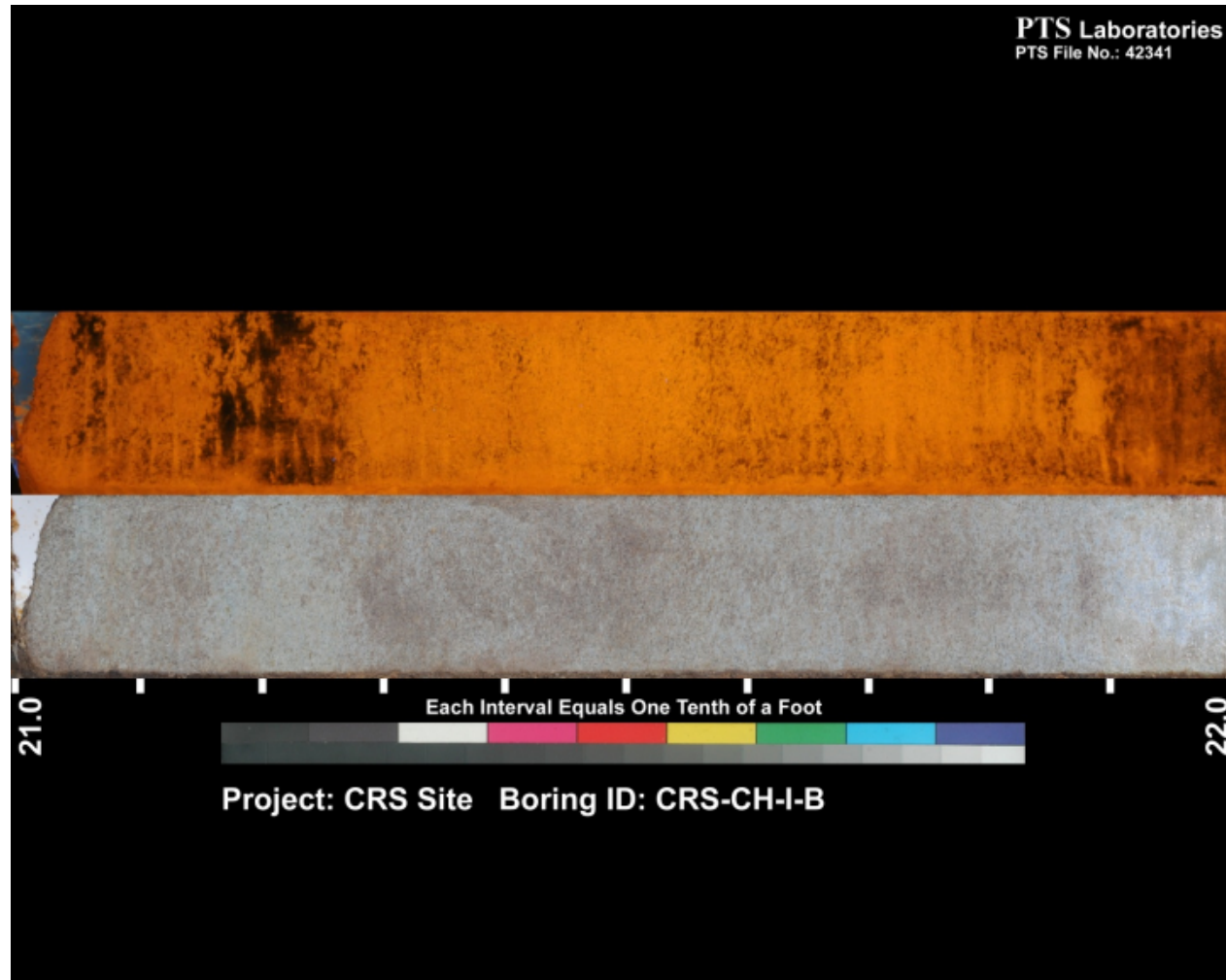
Bedrock Coring-Results



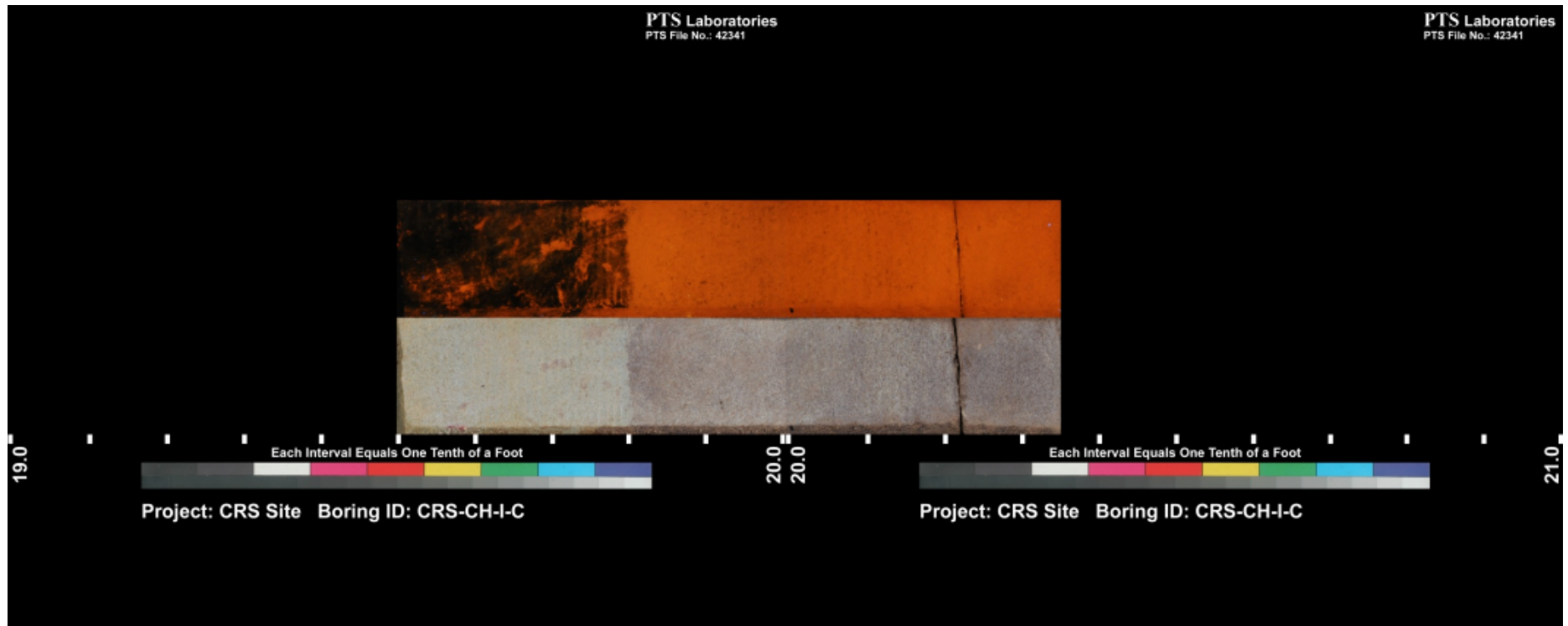
Bedrock Coring-Results



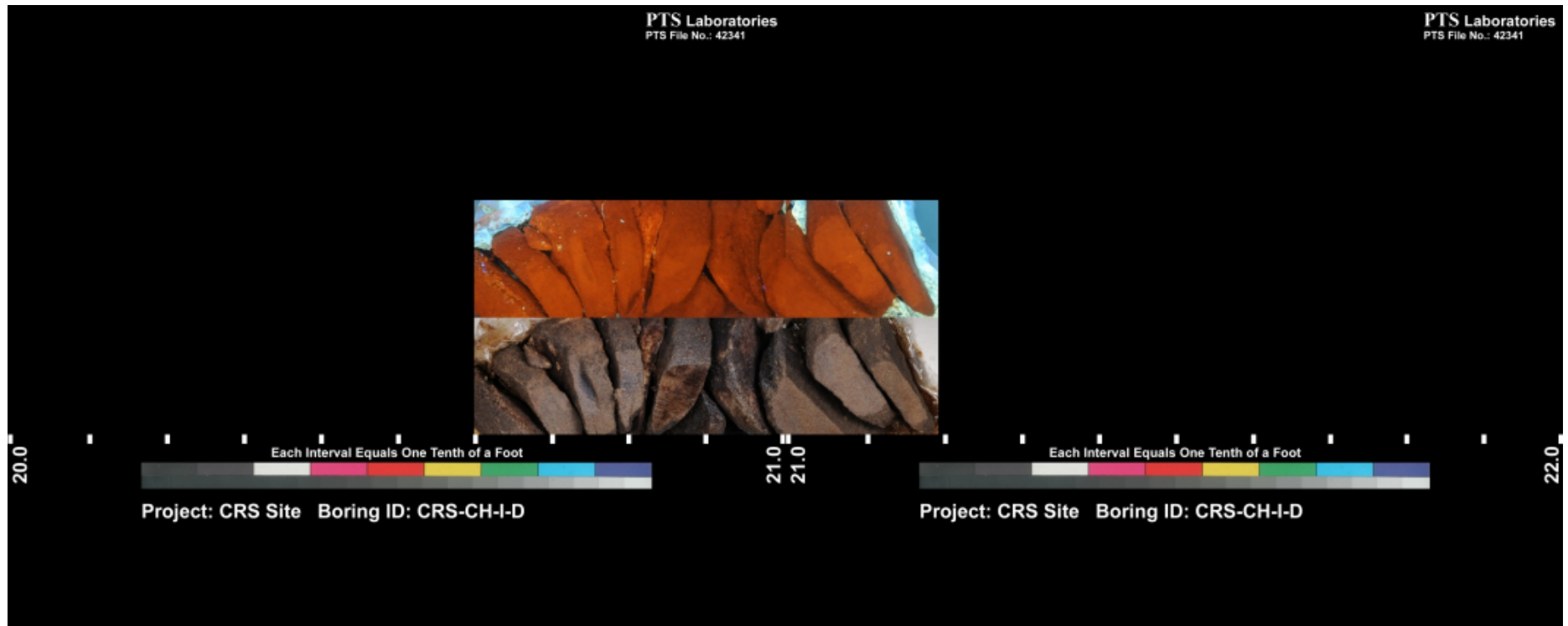
Bedrock Coring-Results



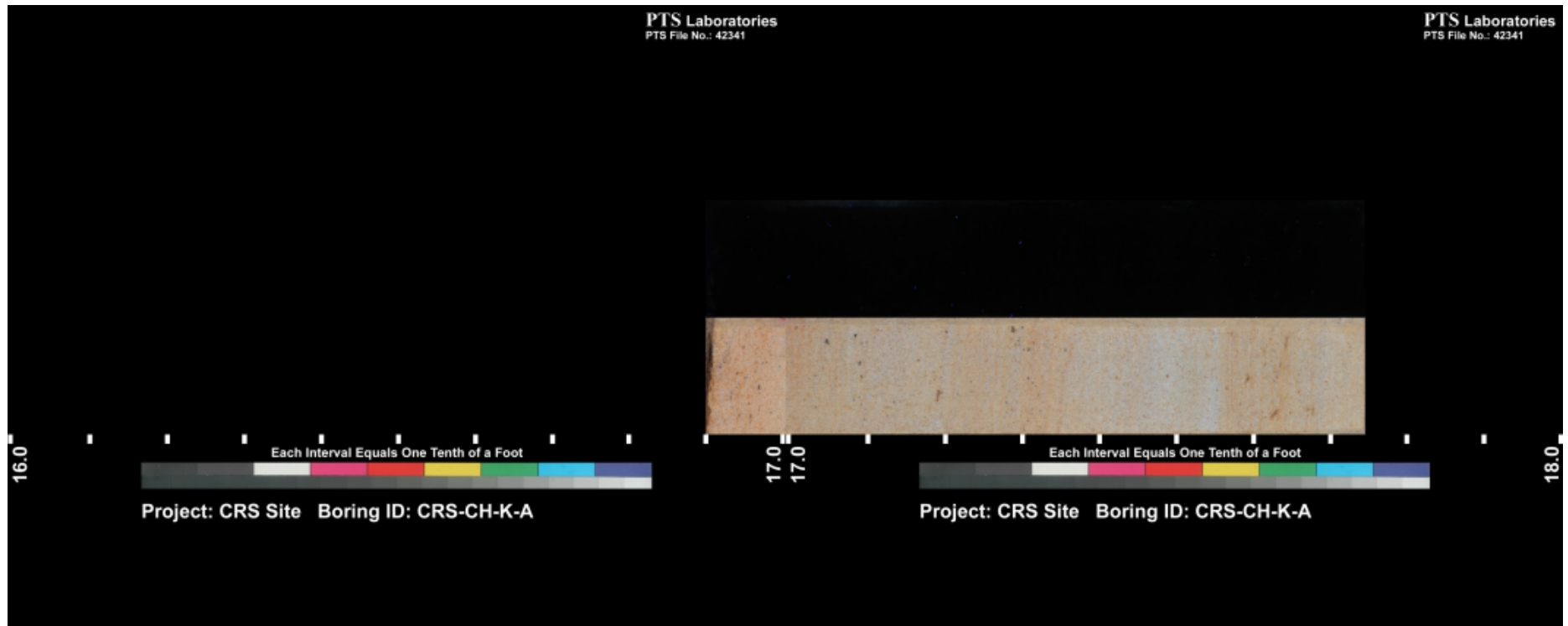
Bedrock Coring-Results



Bedrock Coring-Results



Bedrock Core Petrophysical Testing-Results



Bedrock Coring-Results

- NAPL-saturated bedrock was not observed in CH-J or CH-K. Instead, NAPL was apparent on the bedding plane fracture faces with slight penetration into the host rock.
- NAPL-saturated bedrock was apparent in CH-I, as well as associated with bedding plane fractures. The NAPL was not as heavily stained as that found in previous cores obtained from the same area of the Site.
- Cores from CH-I had the strongest fluorescence.
 - Strongest in 19.8-22.0' interval.
 - NAPL in intergranular porosity of rock.
 - LNAPL staining in fracture zones.
- Core from CH-K did not fluoresce, but NAPL still present at saturations between 3.8 and 5.2% PV.

Bedrock Coring-Results

Mass

- NAPL Volume is around 11 L /m³ (0.30 L/ft³)
- NAPL Mass is around 10 kg/m³ (0.63 lbs/ft³)

SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	METHODS: ASTM D2216 MOISTURE CONTENT, % weight	API RP 40		API RP 40		API RP 40	
				DENSITY		POROSITY, %Vb (2)		PORE FLUID	
				BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	SATURATIONS, % Pv (3)	
								WATER	NAPL
CRS-CH-K-A	16.95	H	9.1	2.05	2.66	22.9	4.1	76.8	5.2
CRS-CH-K-A	17.15	H	9.0	2.06	2.66	22.6	4.1	78.5	3.4
CRS-CH-K-A	17.5	H	9.3	2.06	2.66	22.6	3.5	80.9	3.8
CRS-CH-I-A	16.75	H	8.6	2.09	2.66	21.4	3.3	76.7	7.8
CRS-CH-I-A	17.5	H	8.3	2.11	2.66	20.9	3.4	80.5	3.1
CRS-CH-I-B	21.9	H	9.7	1.99	2.66	25.0	5.7	71.0	6.0

- Assuming 10 foot thick smear zone over 15,000 ft² = 94,500 lbs of mass. NAPL only in discrete fracture sets in peripheral areas.

Bedrock Coring-Results

Dean Stark Residual Saturations

		METHODS:		API RP 40		API RP 40		ASTM D425M, DEAN-STARK	
								PORE FLUID SATURATIONS, % Pv	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	DENSITY		TOTAL POROSITY, %Vb	Initial Fluid Saturations		After Centrifuge at 1000xG	
			DRY BULK, g/cc	GRAIN, g/cc		WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
CRS-CH-I-B	21.1	H	2.00	2.65	24.6	61.8	13.4	19.1	12.1
	NOTE: Dark brown DNAPL produced. Produced water cloudy.								
CRS-CH-I-C	19.9	H	2.01	2.65	24.1	60.5	21.0	19.4	15.5
	NOTE: Dark brown DNAPL produced. Produced water cloudy.								

Bedrock Coring-Results

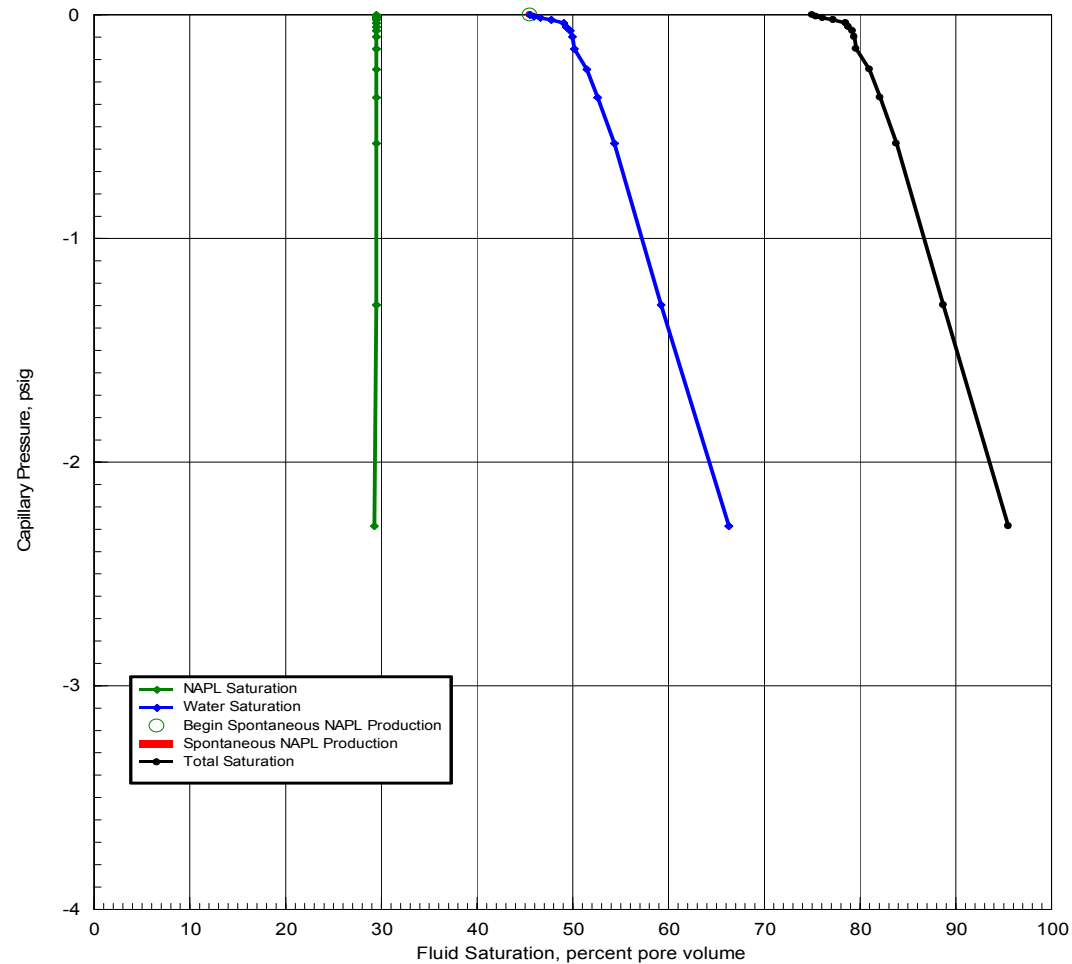
Brown and Caldwell
File No.: 42431

NATIVE STATE (AS-RECEIVED) CAPILLARY PRESSURE Centrifugal Method

Imbibition: Water Displacing Oil - ASTM D6836

Project Name: CRS Site
Project Number: N/A

Sample ID: CRS-CH-I-B
Depth, ft.: 21.3



Bedrock Coring-Results

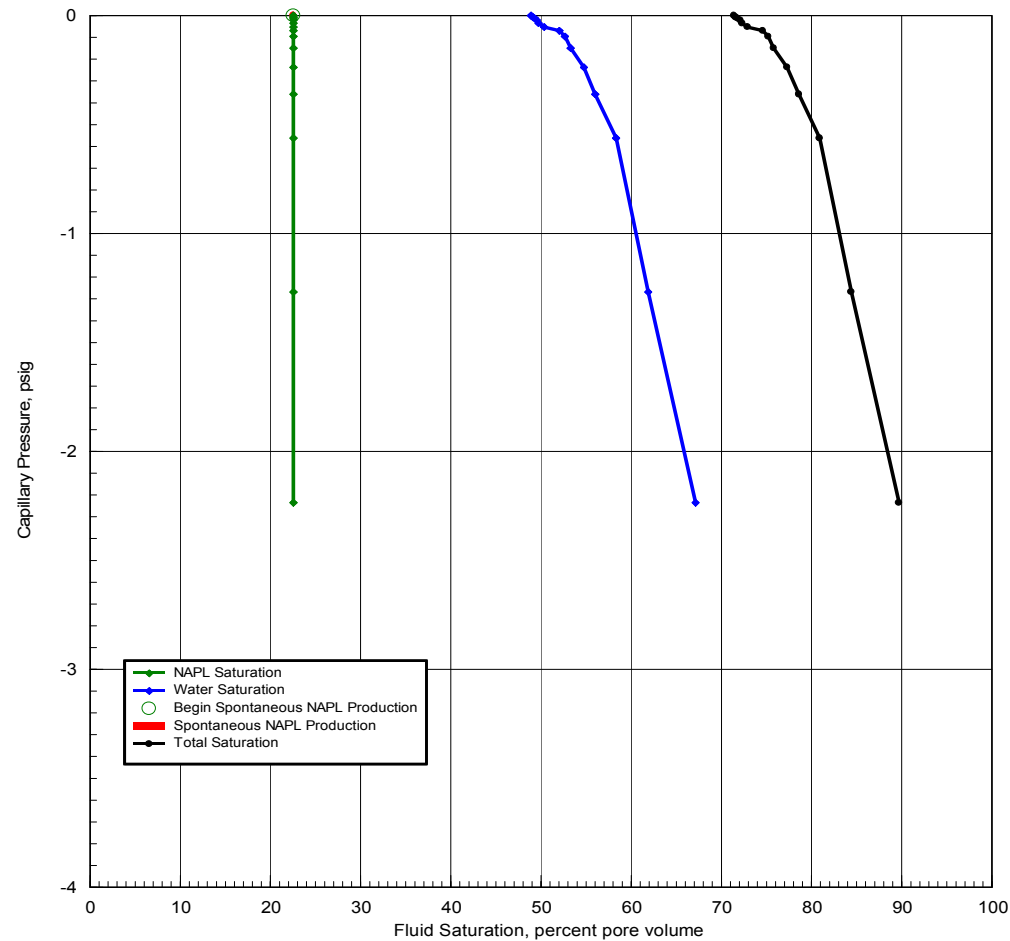
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File No.: 42431

NATIVE STATE (AS-RECEIVED) CAPILLARY PRESSURE Centrifugal Method

Imbibition: Water Displacing Oil - ASTM D6836

Project Name: CRS Site
Project Number: N/A

Sample ID: CRS-CH-I-C
Depth, ft.: 20.1



Chemistry of NAPL Bedrock Coring-Results

- MGP Wastes have a distinct signature. Dominated by BTEX and PAHs. Both NAPL and core samples have identical chemical signature.
- Core samples indicated lower chemical concentrations but samples biased toward lower saturation intervals.
 - Benzene – 980 mg/kg
 - BTEX – 2,740 mg/kg
 - Total PAHs – 8,263 mg/kg
 - VPH – 8,300 mg/kg
 - EPH – 3,100 mg/kg
 - Stryene – 1,200 mg/kg
 - Chlorinated compounds, including methylene chloride and c12DCE were detected.

Summary

- Mobility and Recoverability of NAPL is limited:
 - Limited NAPL detected in wells
 - NAPL mass distributed below the water table and water filled porosity an impediment to mobility
 - Core sampling indicates:
 - No drainage of NAPL in the new cores
 - Historical select locations with some drainage
 - Viscous NAPL in fracture sets
 - Petrophysical sampling indicates saturation levels below theoretical number.
 - Dean Stark and Water Displacing Oil Imbibition Curves show no to limited mobility.

Hydrogeologic Conceptual Site Model Highlights

- Groundwater flows through the Berea Sandstone in both the UBZ and LBZ toward and discharges into the River, with a slight deflection toward the stormwater outfall.
- The River stage is regulated by the fixed dam located less than ½ mile downstream from the site.
- The Berea Sandstone possesses primary permeability with preferential flow through thin bedding plane fractures.
- Groundwater seeps are present along both banks of the River at similar elevations and are surface expressions of the groundwater flow zones toward the River.
- No NAPL discharges from the seeps.
- Residual NAPL is trapped in bedrock matrix and along bedding plane fractures, and is largely immobile and unrecoverable.
- Site conditions are favorable for a TI Waiver.